DOMESTIC ENERGY SAVINGS WITH GEYSER BLANKETS

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ABSTRACT

The Demand Side Management intervention of having hot-water cylinders (geysers) wrapped with blankets showed some serious defects in the installations in the Western Cape. Energy audits by the Cape Peninsula University of Technology Measurement and Verification Team revealed a number of shortcomings, including poorly secured blankets; inadequate covering of the piping of at least 1 meter on the inlet and 2 meters on the outlet side; exposed parts of the cylinder and fittings; and inaccurate determination of the water temperatures. In order to quantify the extent of such defects, a pilot study was conducted in the CPUT laboratories to measure the seriousness of such deviations. Results quoted in this paper indicate that standing losses could be reduced by up to 27,0 per cent by properly wrapping both the hot-water cylinder plus 3 meters of piping. If only the hot-water cylinder is covered properly, then the standing losses could be reduced by up to 21,7 per cent. By selecting lower temperature set-points of the geyser between 65^{0}C and 50^{0}C, the energy required to re-heat the water inside the cylinder could be reduced by up to 16,0 per cent, or approximately 1 per cent per 1^{0}C. This paper therefore exposes inherent problems encountered in the Western Cape project, which need to be addressed before future roll-out programmes of this nature are launched elsewhere.

1. INTRODUCTION

One year ago, ESKOM launched a 'geyser blanket' roll-out programme to reduce energy standing losses from domestic hot-water cylinders. This Demand Side Management intervention was aimed at reducing the household energy demand in the Western Cape and thus preventing, or at best, reducing imminent regional power cuts. Insulating blankets were to be wrapped around 180 000 hot-water cylinders (geysers) and the corresponding adjoining piping up to a length of 3 meters.

1.1 Project Background

Three Electricity Services Companies (ESCOs) were contracted to urgently manufacture and install the approved insulating material. New factories were built within weeks and production commenced within two months of commissioning to help save the targeted 400 MW of power. Subsequent energy audits by the Cape Peninsula University of Technology Measurement and Verification Team revealed a number of shortcomings in the execution of this hastily prepared programme. These include poorly secured and loosely wrapped blankets; inadequate wrappings around the piping of at least 1 meter on the inlet and 2 meters on the outlet side; exposed parts of the cylinder and fittings; and inaccurate determination of the water temperatures. In order to establish the effectiveness of properly installed blankets, as well as the seriousness of observed deviations, a pilot study was conducted in the CPUT laboratories to help determine more realistic baselines.

According to the HWC manufacturers, the condition of the thermostats and the heating elements should be checked every 5 years. Even if elements are still in working condition, they could be drawing exceptionally high loads [1]. The relationship between losses, element size and the maximum demand on the system is a complicated one and is affected also by people's habits in terms of when they use water for washing, bathing, etc. The relationship is also affected by the maximum temperature at which people use water, or rather at what temperature the thermostat is set [2].

1.2 HWC insulation

The present amount of insulation on a HWC is designed to conform to SABS requirements for standing losses. An increase of the thickness of the insulation would reduce these losses. Calculations have shown that by doubling the thickness of the insulation, the standing losses would decrease by 31% [2]. The best way of increasing the thickness of the insulation is to cover the HWC with an adequate HWC insulation blanket, provided the installation allows enough room for such retrofits.

1.3 Pipe insulation

In South Africa, very few architects and building inspectors have paid any attention to heat losses from hot-water pipes. Therefore many pipes are completely exposed. (Others are grouted into the wall, which is not too bad because masonry is a poor conductor of heat). It is therefore difficult to determine the resulting wastage of heat, since it depends on water consumption and lengths of the piping involved. The potential for saving energy by adequately insulating hot-water pipes amounts to approximately 5% of the total hot-water energy [2]. The most convenient and effective way to insulate pipes is to fit them with pre-formed foam pipe lagging or to wrap them with insulating material similar to HWC blankets. Generally, 1m to 2m from the HWC will suffice [3].

2. SYSTEM SIMULATION

The ETU geyser blanket tests were carried out with a conventional HWC in the laboratories of the Department of Mechanical Engineering of the CPUT.

2.1 Insulation Material Tests

The ETU geyser blanket tests were conducted with a Pregare Geyser Blanket, used by the major ESCO. The Pregare Geyser Blanket consists of insulating material, assisted by an air gap and an outer reflective coating. The Council for Scientific and Industrial Research (CSIR) conducted large-scale fire tests, and the South African Bureau of Standards (SABS) did moisture absorption and fungal attack tests on the insulating material used for the blankets. The Pregare Geyser Blankets comply with all these test requirements and are acceptable as an outside wrapping for HWC in the domestic and industrial sectors [4].

Pregare Manufacturing estimated that by fitting HWCs with one of their blankets, the average time between cut in of the electrical element at a set point of 60°C would increase from 16 hours 39 minutes to an average time of 20 hours 59 minutes. The corresponding standing losses would decrease from 2.024 kWh to 1.607 kWh per day, saving 21% [4].

Table 1: Comparison of covered and uncovered HWCs by Pregare Manufacturing [4]

	Bare	With Blanket	
Average Time until next cut in	16:39:30	20:59:30	hh:mm:ss
Average re-heat time from 55 deg C	00:19:00	00:18:15	hh:mm:ss
Standing Loss	2.024	1.607	
Saving		21%	

Graphically, the condition is shown in Figure 1

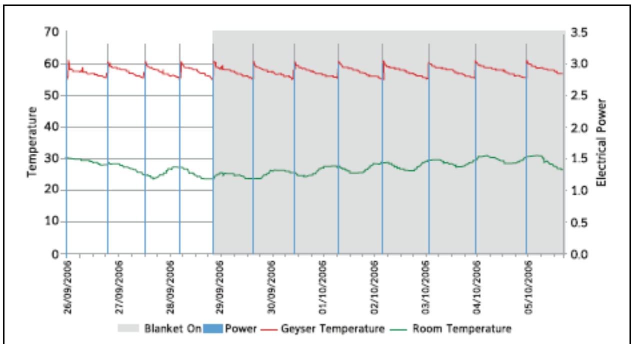


Figure 1: Comparison of geyser and room temperatures with and without a Geyser Blanket [4]

2.2 Hot-water cylinder

The HWC used for the ETU tests was a KWIKOT 600 Dual hot-water cylinder of 150-liter capacity used in many South African households.

Table 2: Technical Data of KWIKOT 600 Dual

Model No.	R6150 U2SLG1
Water capacity	150 l
PN	3,0 kW
Voltage	230 V ~
Operating pressure	0 - 600 kPa
Mass	39 kg
Standing loss / 24 Hrs	2,3 kWh

There was no wind or draft in the ETU laboratory and the geyser was not exposed to sunlight. The ambient temperature in the laboratory ranged from 18°C to 22°C over the test period

3. METERING EQUIPMENT

Laboratory measurements were conducted as follows :

3.1 Wattmeter

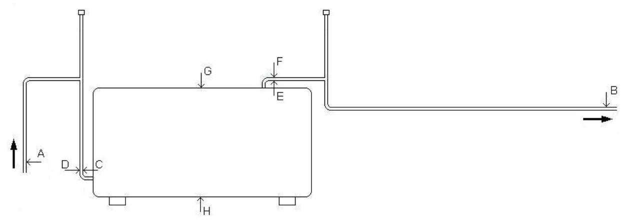
The power consumption of the HWC was measured during test runs with a Songxia wattmeter of specifications shown in Table 3.

Table 3 : Specifications of the Songxia Wattmeter

Type DD282
1 phase 2 wire
240 V / 50 Hz
20 (80) A
300 revs / kWh

3.2 Temperature sensors

Resistance temperature detectors (RTD) with a resistance of 100 Ohm (PT100) and thermocouples (TC) were used for the temperature readings. The sensors were placed at eight different points on the HWC and on the piping, as shown in Figure 2. The sensors connected to the pipes were wired down with copper wire to ensure better heat transmission from the water to the sensors. They were also taped down with insulation tape to prevent the wires from coming loose, before being covered by the lagging.



Key:

A Inlet - cold water (TC)
B Outlet - hot water (TC)
C HWC - cold water inlet underneath the pipe lagging (PT100)
D HWC - cold water inlet on top of the pipe lagging (PT100)
E HWC - hot water outlet underneath the pipe lagging (PT100)
F HWC - hot water outlet on top of the pipe lagging (PT100)
G HWC - top (TC)
H HWC - bottom (TC)

Figure 2 : Positions of the temperature sensors

To prevent the ambient temperature from effecting the measurements, the exposed sensors were covered by an insulating woollen material. The others were covered by the geyser blanket or by the pipe lagging and therefore protected from ambient influence.

3.3 Data logging by ' *Labview'*

The measured readings of the eight temperature sensors were logged onto a computer with the help of a National Instruments SCB 68 data logger board. With the help of a *'Labview'* software package the incoming data was scanned, filtered and saved in a spreadsheet for further processing. For better operation of the logging instrument, a virtual front panel which included a waveform chart showing the temperature values of the sensors and a control unit to set the interval time of the logging was developed. Figure 3 shows the block diagram of the *'Labview'* data logging setup.

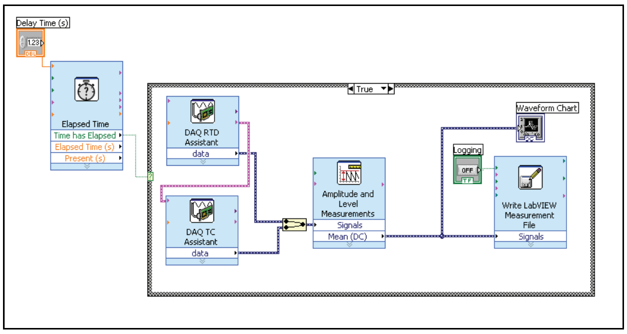


Figure 3 : Block diagram of the 'Labview' setup

4. TEST METHODOLOGY

According to a field audit, sampling 1 000 out of the 180.000 HWC which had been fitted with geyser blankets by the three ESCo's, over 50% of the hot-water cylinders were set at a temperature between 50°C and 52°C. For the ETU laboratory tests, the HWC was set at 50°C, 55°C and 65°C to also capture the manufacturers' set point.

To achieve a reduction in the energy required to keep the HWC at the constant set-point of the thermostat setting, a geyser blanket of 50 mm, and triple-layered insulation material, was wrapped around the cylinder. The same insulation material was also wrapped around the piping for 1m on the inlet side and for 2m on the outlet side. In order to establish the effectiveness of the insulation material at different positions, it was removed systematically, followed by repeated test runs for the chosen temperatures.

4.1 Standing losses

According to I.E. Bosman and Prof. L.J. Grobler of the North-West University, Potchefstroom [1], the impact of the standing losses by installing blankets to electric hot-water cylinders in Southern Africa are calculated as follows:

Energy losses for an uncovered HWC:

$$E_{LOSS} = -1{,}9307 \times (Ta - Ts) \qquad [1]$$

Energy losses for a HWC covered with a geyser blanket:

$$E_{LOSS} = -1{,}582 \times (Ta - Ts) \qquad [2]$$

With *Ta* being the ambient temperature and *Ts* the set point of the HWC.

4.2 Thermal conductivity

Thermal conductivity, 'k', is the intensive property of a material that indicates its ability to conduct heat. It is defined as the quantity of heat, *Q*, transmitted in time *t* through a thickness *L*, in a direction normal to a surface of area *A*, due to a temperature difference Δ*T*, under steady state conditions and when the heat transfer is dependent only on the temperature gradient.

$$k = \frac{Q}{t} \times \frac{L}{A \times \Delta T} \quad \left[\frac{W}{m \cdot K}\right] \qquad [3]$$

Where: *k* is the thermal conductivity in *W/m·K,*
Q is the heat flow rate in *W/s,*
t is the time in *s,*
L is the length in *m,*
A is the area in m^2,
T is the temperature in *K.*

4.3 Reheating losses

The objectives of these tests was to measure the energy-saving potential for reheating the water in the cylinder to the set temperature after draining a chosen amount of hot water.

To simulate the water usage of a household, 25 liter of hot water was drawn for a shower ; and 40 liter for a bath, respectively. These amounts of water were specified by the Energy Technology Unit (ETU), based on previous tests [3]. Each test was carried out over a period of one hour and the temperatures at the sensors and the corresponding energy consumption, were recorded.

Five test cases were developed for the reheating losses tests for draining the specified amounts of water.

Table 4: Test cases for the reheating tests

TEST	COVERED AREAS	
	HWC	PIPES
1	-	-
2	X	-
3	X	X (1m outlet)
4	X	X (2m outlet)
5	X	X (2m outlet + 1m inlet)

5. RESULTS

With the HWC and the piping fully exposed, the measured energy consumption was 2,3 kWh/day. The average cut in time was measured at 6 hours and 14 minutes, as shown in Figure 5.

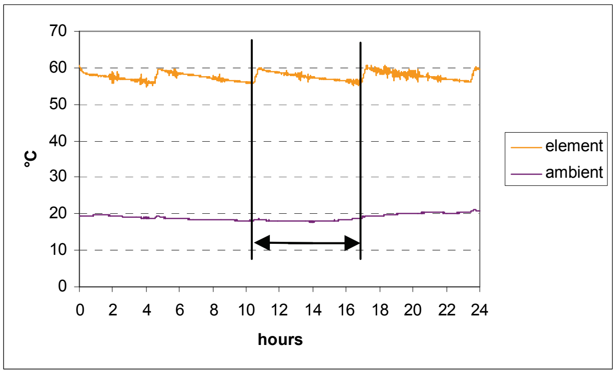


Figure 5 : Temperature gradient over 24 hours of bare HWC and bare Pipes with the element set at 65°C at an average ambient temperature of 19°C.

The second 24-hour test runs were performed with the hot-water cylinder covered with the Pregare Geyser Blanket and both the hot and the cold-water pipes fully wrapped with pipe lagging. The average cut in time measured increased to 9 hours and 22 minutes at an average ambient temperature of 20°C and an average element temperature of 57,6°C, shown in Figure 6. The corresponding measured energy consumption was 1.68 kWh/day.

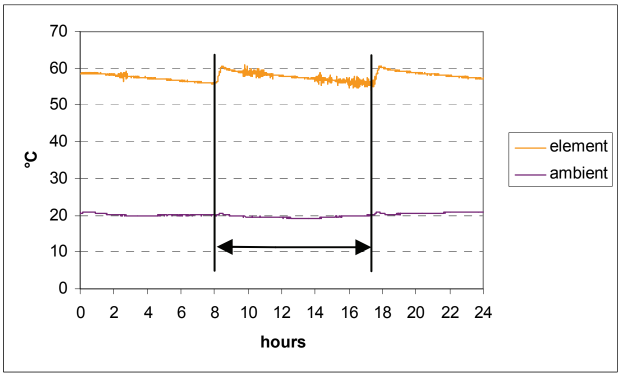


Figure 6 : Temperature gradient over 24 hours of fully covered HWC + Pipes with the element set at 65°C at an average ambient temperature of 20°C.

In Table 5, the standing losses, the savings and the average cut-in times of the different test runs are summarised.

Table 5 : Standing losses of the hot-water system

	No lagging	Pipes lagged	Geyser covered	GB+pipes lagged
Standing loss kWh/day	2.3	2.0	1.8	1.68
Savings %	/	13.04	21.74	26.97
Cut-in time hh:mm:ss	06:14:20	07:20:39	08:12:59	09:22:11

5.1 Calculation of the standing losses

With the equations [1] and [2] the worst case standing losses of the HWC with and without a geyser blanket are calculated as follows with Ta being the ambient temperature and Ts the set point of the HWC:

- With geyser blanket:
  For Ts = 65°C and Ta = 18,45°C

  → E_{LOSS} = -1,582 * (18,45 – 65) = 73,64 W

and over a period of 24 hours:

→ E_{LOSS} = 73,64 W * 24 h = 1767,41 Wh/day
= 1,77 kWh/day

- Without geyser blanket:
  For Ts = 65°C and Ta = 19.01°C

  → E_{LOSS} = -1,9307 * (19,01 – 65) = 88,79 W

and over a period of 24 hours:

→ E_{LOSS} = 88,79 W * 24 h = 2131,03 Wh/day
= 2,13 kWh/day

In Table 6, a comparison is shown between the calculated and measured standing losses of the hot-water system over the period of 24 hours at a set point of 65°C and average ambient temperatures of 18,5°C and 19,0°C, respectively.

Table 6 : Comparison of calculated and measured standing losses at a set point of 65°C

	Standing losses in kWh/day	
	Calculated	**Measured**
With geyser blanket (Ta = 18,45°C)	1,77	1,80
Without geyser blanket (Ta = 19,01°C)	2,13	2,30

5.2 Calculation of the energy losses

The energy losses of the hot-water system E_{LOSS} are the standing losses of the HWC and the heat losses of the pipes. The energy losses of the hot-water systems are calculated as follows:

$$E_{LOSS} = E_{EL} - E_{WATER}$$

Where E_{EL} is the electrical energy put into the system and E_{WATER} is the energy of the hot water. E_{WATER} is determined as follows:

$$E_{WATER} = m_{WATER} * Cp_{WATER} * \Delta T_{WATER}$$

Where: E_{WATER} is the energy of the hot water in *J*,
m_{WATER} is the mass of the water in *kg,*
ΔT_{WATER} is the temperature difference of the water in *K,*
Cp_{WATER} is the specific heat of water (*4,18 kJ/ kg·K*).

(a) At 65°C set point, 25 liter water consumption and an uncovered hot-water system :

$$E_{LOSS} = 1{,}505kWh - (25kg * 4{,}18\ kJ/kg\cdot K * (65-20)K) = 1{,}505kWh - 1{,}306kWh = 0{,}199kWh = \underline{199\ Wh}$$

(b) At 65°C set point, 25 liter water consumption and a completely covered hot-water system :

$$E_{LOSS} = 1{,}325kWh - (25kg * 4{,}18\ kJ/kg\cdot K * (65-20)K) = 1{,}325kWh - 1{,}306kWh = 0{,}019kWh = \underline{19\ Wh}$$

When having a shower, the energy loss is thus appreciably lower (up to 180 Wh) for the completely covered geyser if it is set as high as 65^0C. Tests are continuing for lower temperature settings.

6. CONCLUSION

According to Table 5, standing losses may be reduced by up to 27,0 per cent by properly wrapping both the hot-water cylinder plus 2 meters of outlet piping plus 1 meter on the inlet side. If only the hot-water cylinder is covered properly, then the standing losses may be reduced by up to 21,7 per cent. This measured value is confirmed in Table 6. By lagging the pipes alone up to 3 meters, savings of approximately 13 per cent were achieved.

It is also shown that when drawing water off for a shower, the reduction in standing losses from a geyser completely covered, can be as high as 180Wh at 65^0C.

7. REFERENCES

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